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USSR: Failing Reliability of Pipeline Gas Turbines

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An Intelligence Assessment

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USSR: Failing Reliability of Pipeline Gas Turbines

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Key Judgments

Information available as of 10 February 1988 was used in this report.

Growing problems with the reliability of domestically produced 16- and 25-megawatt (MW) turbines threaten to undermine the capability of the Soviet gas pipeline system to deliver adequate volumes of gas to the industrialized western regions of the USSR during the winter months. Following the 1981 US embargo on pipeline equipment, Moscow launched a crash program to develop indigenous production capacity for these large turbines. While the program was successful in terms of quantities produced, the emphasis on getting production under way quickly led to shortcomings in design and manufacture. As a result, according to Soviet press reports, numerous turbine failures have already occurred and more are expected to cause disruptions in gas deliveries to some areas. 25X1

So far the Soviets have been able to deal with the potentially debilitating effects of turbine failures because of excess capacity along many lines and the redundancies and flexibility of its highly integrated pipeline network. 25X1 the pipeline network—despite its flexibility—will not be able to meet peak winter demand in some regions by 1990:

- The pipeline network transporting gas to the Baltic, Belorussian, and Leningrad regions (the Northern Lights system) apparently has been nearly fully utilized since 1985; turbine failures would result in reductions in gas deliveries.
- 25X1 the key pipeline system transporting gas from West Siberia to the central and western regions of the USSR show that by 1990 excess transport capacity could fall to as little as 10 percent during peak winter periods.
- The Siberia–to–Western Europe pipeline is unlikely to be affected because it is largely powered by more reliable imported turbines.

Because natural gas will be the major source of growth in the USSR's energy supply in the 1990s, Moscow can ill afford disruptions in gas deliveries. The expected shortfalls in many areas of Moscow's Long-Term Energy Program will put pressure on planners to boost dependency on natural gas. This, together with turbine failures, would reduce peak-use excess pipeline capacity even further. Regional disruptions in gas deliveries, if prolonged or exacerbated by increasingly frequent turbine breakdowns, could develop into a problem of national proportions. 25X1

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Cutbacks in gas deliveries would result in some combination of increased use of fuel oil, reduced oil exports, lower electricity production, and reduction in industrial output. Each of these consequences carries a heavy cost, particularly considering the importance of expanding industrial output to Gorbachev's modernization program. 25X1

If disruptions in gas deliveries threaten to reduce oil exports or electricity production, we believe Moscow most likely would resume imports of Western turbines to improve the reliability of the natural gas network. The economic costs of prolonged natural gas disruptions are far greater than the hard currency expenditures required to obtain needed equipment. While the Soviets could conceiveably opt for a domestic solution to the problem by developing new, more reliable turbines, increasing redundancy along each line, or building more reliable electric-drive compressor stations, each option carries a higher economic cost than an "import option." In fact, the Soviets reportedly have already made inquiries to some Western firms about the availability of 10-, 16-, and 25-MW gas turbines. Western companies would welcome any opportunity to increase sales and could be expected to vie strongly for Soviet business. The US-USSR Joint Commercial Commission meeting scheduled next month could provide a forum for Moscow to pursue this issue with US businessmen. 25X1

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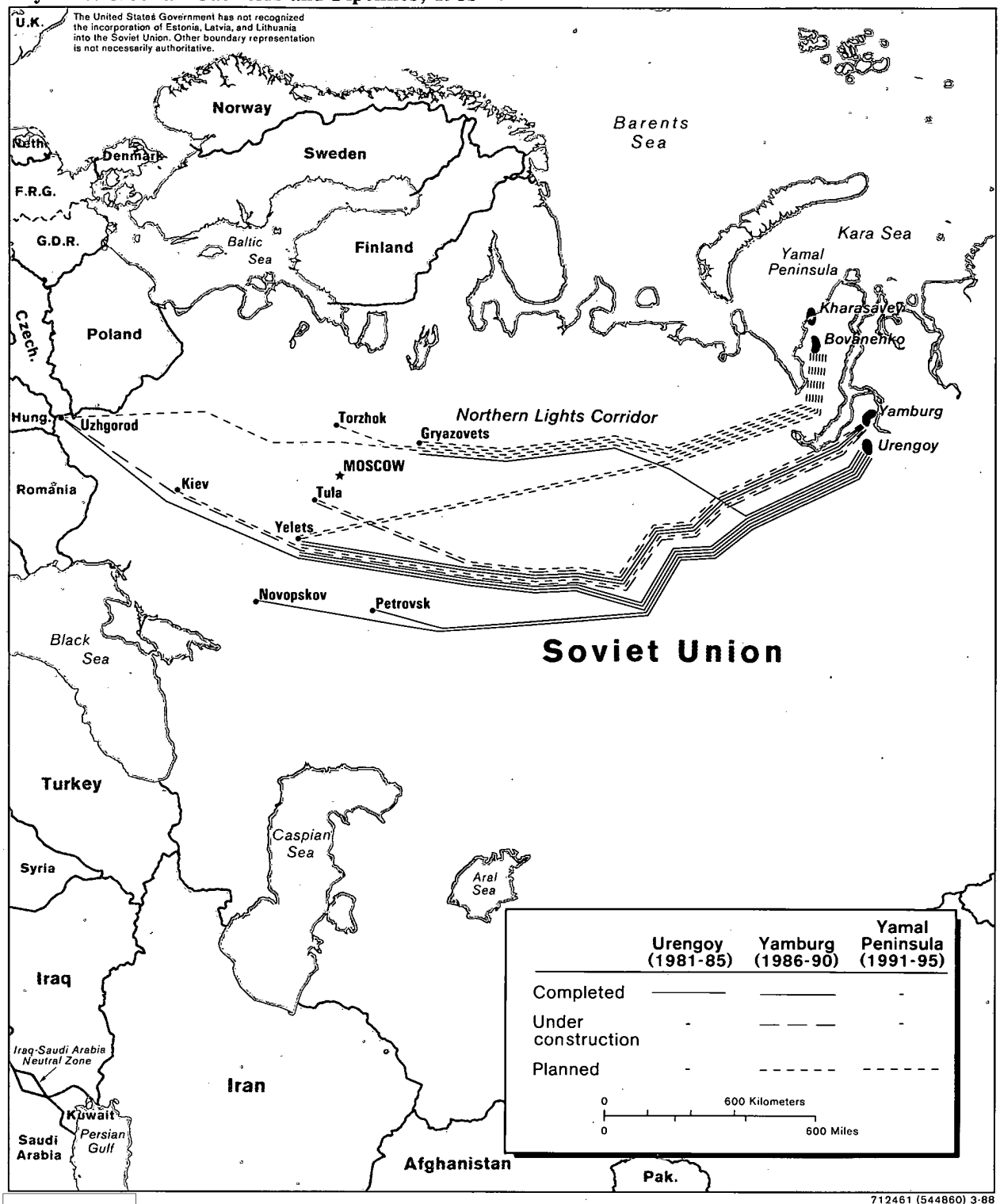
Figure 1
Key West Siberian Gasfields and Pipelines, 1981-95



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The Importance of Keeping the Gas Moving

Natural gas—which is displacing oil as the largest single component of Soviet primary energy production—will be the major source of growth in the USSR's energy supply for the remainder of this century. The country is endowed with enormous gas reserves in West Siberia, but Moscow must continue to expand the gas pipeline network to move this gas to both domestic and foreign consumers. To transport West Siberian gas 3,000 to 4,000 kilometers to the European regions of the USSR (roughly the distance from New York City to Phoenix, Arizona), the Soviets use large-diameter, 1,420-millimeter gas pipelines operating at pressures up to 75 atmospheres (see figure 1). Gas turbines fueled from the pipelines—with power ratings of 10 megawatts (MW) and greater—are the preferred source of power for compressors that move the gas through the pipelines (see inset).

Before 1981 the USSR had long used indigenously produced 6- and 10-MW turbines to power compressors on its large-diameter pipelines dedicated to domestic consumers. Using a portion of its anticipated hard currency earnings, Moscow installed more powerful and higher quality imported equipment on lines that serve customers in Western and Eastern Europe. Soviet ability to continue this strategy was constrained by the quantum leap in pipeline construction anticipated for the 1981-85 period—from 9,000 km during 1976-80 to 20,000 km during 1981-85. Moscow's program to manufacture the more powerful pipeline turbines languished until US sanctions on oil and gas equipment were imposed in 1981 as a response to the Soviet-inspired imposition of martial law in Poland.[1]

[1] These sanctions followed the US embargo on grain and high-technology products imposed in 1980 after the Soviet invasion of Afghanistan.

Development of Soviet Gas Turbines: Taking Its Time

The USSR has long had difficulty in developing and producing gas turbines for pipeline service. During the 1960s the Soviet demand for lightweight, efficient, and more powerful gas turbines was not great, and the USSR's large and bulky 4- and 6-MW gas turbines were adequate for Moscow's needs. Subsequently, however, Soviet gas output soared—from 45 billion cubic meters (m^3) in 1960 to nearly 200 billion m^3 in 1970—as new and productive gasfields were developed in the remote areas of Central Asia and West Siberia. The Soviets began to lay large-diameter (1,020 mm and greater) gas pipelines at an ever-increasing pace.

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Despite growing demand, Soviet industry during the 1970s continued to make halting and mostly unsuccessful attempts to develop and manufacture the larger 16- and 25-MW gas turbines necessary for large-diameter gas pipeline service. Although some prototypes were assembled, no unit entered serial production during the 1970s. Typically, following the assembly of prototypes, testing was delayed, took a long time to complete, and led to a decision to postpone serial production. Moreover, the urgency of the program to manufacture more and better turbines was lessened by the Soviets' reliance on the West for a large number of high-quality 10-, 13-, and 25-MW turbines for use on 1,420-mm gas pipelines. During 1971-80 Moscow imported nearly 300 gas turbines that provided more than one-third of the aggregate power installed on 1,420-mm gas pipelines. Imported turbines provided a "safety valve" that tended to minimize the need for the Soviets to manufacture larger and better turbines.

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The USSR originally contracted with Western firms to buy 120 US-designed 25-MW turbines for installation on the Siberia–to–Western Europe gas export pipeline. Moscow probably was also counting on additional Western imports to satisfy a significant portion of the demand for pipeline turbines during 1981-85. The US embargo imposed in 1981, however, foreclosed this option at least temporarily and highlighted Soviet technological inferiorities to domestic and foreign leaders alike.

Reliance on Domestic Producers

Faced with the prospect that the US embargo might delay delivery of the 120 Western turbines needed for the gas export pipeline and preclude additional purchases for its five domestic gas pipelines planned during 1981-85, Moscow initiated a crash program to produce 16- and 25-MW turbines.[3] Not surprisingly, this concerted effort yielded results. During 1982-83, the Soviets began serial production of three models of gas turbines suitable for large-diameter pipelines:

- *GTN-16*, an industrial 16-MW gas turbine designed and manufactured at the Sverdlovsk Turbomotor Plant.
- *GPA-Ts-16*, a 16-MW aeroderivative turbine developed by the Ministry of the Aviation Industry from NK-8 aircraft engines; the current workhorse of the gas pipeline network, this model satisfies about one-third of Moscow's current demand for large-diameter pipeline turbines.
- *GTN-25*, a 25-MW industrial turbine assembled in Leningrad and frequently hailed by Moscow as a more than worthy substitute for the US Frame-5 turbine.

[3] Because of far higher costs, substantial inefficiencies, and much longer installation periods, expanded production and use of smaller domestic turbines was not a viable option. Moreover, because Moscow also planned to accelerate construction of smaller, regional distribution pipelines, many of the USSR's less powerful turbines were probably earmarked for installation on these pipelines.

A Success of Sorts . . .

In terms of *quantity,* the crash program has been a success. We estimate that aggregate power provided by Soviet production of 10-, 16-, and 25-MW turbines increased from about 1,000 MW in 1980 to 2,000 MW in 1983. The newly developed gas turbines accounted for nearly 50 percent of the total power installed on two domestic gas pipelines laid during 1984-85 (see table). In a recent interview with the Joint Economic Committee of Congress, one of Gorbachev's key economic advisers, Abel Aganbegyan, characterized increased production of the turbines as a major advance for Soviet technology.

Moreover, development and serial production of 16- and 25-MW gas pipeline turbines substantially reduced—if not eliminated—the Soviet Union's need to import Western gas turbines (see figure 2). Since the delivery during 1983-85 of the 120 US-designed Frame-5 gas turbines originally purchased before the embargo, we know of no Soviet imports of Western turbines for pipeline use, although the Soviets continue to import spare parts to service and maintain turbines imported before 1985.

. . . But Short on Quality

In terms of *quality,* however, the Soviet program has fallen far short of expectations. Recent articles in the Soviet gas industry journal—including two by directors of gas transport associations—have been sharply critical of the poor reliability and inadequate performance of the 16- and 25-MW turbines developed after the US embargo:

- In 1986 GTN-16 turbines on average operated only 620 hours before an unscheduled shutdown. (Comparable statistics for Western turbines run into the thousands of hours.) These turbines were reportedly out of service on average 45 percent of the time. Numerous design flaws were cited as key causes of the turbine's "very low reliability."
- GTN-25 turbines reportedly ran on average 526 hours before a failure occurred that required an unscheduled shutdown. Soviet design engineers originally presumed that these turbines would operate roughly 3,000 hours before an unscheduled

Sources of Compressor Power on the Urengoy–Center I and Urengoy–Center II Gas Pipelines, as of Yearend 1986

Turbine Type	Number of Units Installed	Aggregate Power Provided (*MW*)	Share of Pipelines' Total Power Supply (*percent*)
Total	**370**	**5,063.5**	**100.0**
Imported 25 MW	12	300	5.9
Soviet 10 MW	128	1,280	25.3
Soviet 16 MW [a] (industrial)	20	320	6.3
Soviet 16 MW [a] (aeroderivative)	111	1,776	35.1
Soviet 25 MW [a]	12	300	5.9
Soviet 12.5 MW (electric)	87	1,087.5	21.5

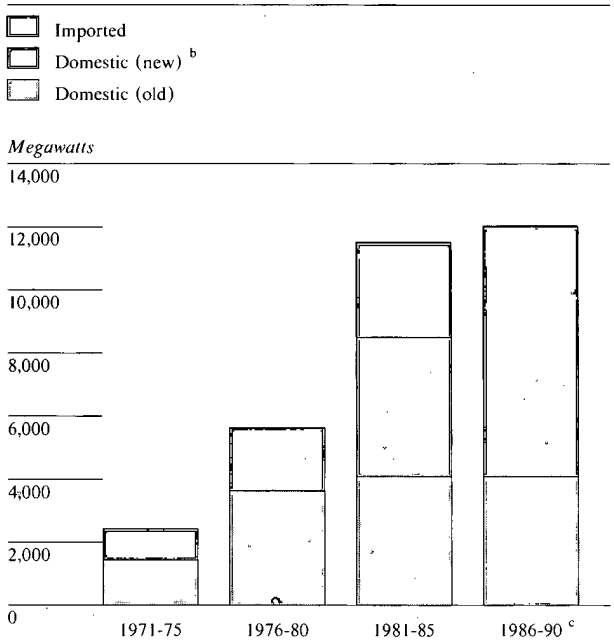
[a] Production of these turbines began in 1982-83.

shutdown, but a large number of design and manufacturing defects have reportedly been discovered. Despite more than 200 technical modifications, the Soviet press indicates that there has been no "substantial improvement" in the performance of the GTN-25.

- The 16-MW aeroderivative turbines reportedly have an operating life of only five years before the units have to be discarded. Moreover, the press indicates the gas turbines need to be removed and overhauled at the factory after 10,000 to 11,000 hours of operation. (In contrast, models of a US aeroderivative turbine during the 1970s ran on average 41,000 hours before the turbines were removed and overhauled.) According to the Soviet press, more than 130 6- and 16-MW aeroderivative turbines were idled in September 1987 awaiting spare parts (see figure 3).

The Soviet gas turbine program historically has experienced problems because of low-quality steels and obsolete technology for fabricating turbine blades and rotors. But the recent problems with the GTN-25

Figure 2
Power Provided by Imported and Domestic Gas Turbines Installed on Soviet 1,420-mm Gas Pipelines [a]



[a] Estimated.
[b] Production of these turbines began in 1982-83.
[c] Planned.

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reported in the Soviet press are not limited to a single section of the turbine. The system monitoring and controlling ignition works poorly, frequently causing the protective linings of the combustion chamber to burn up. Control instrumentation for countering the effects of vibration is ineffective, and some shaft bearings are prone to collapse under loading.[4]

[4] Development of pipeline turbines has been hampered partly because the civilian program historically has been accorded a low priority relative to the development of turbines for military aircraft.

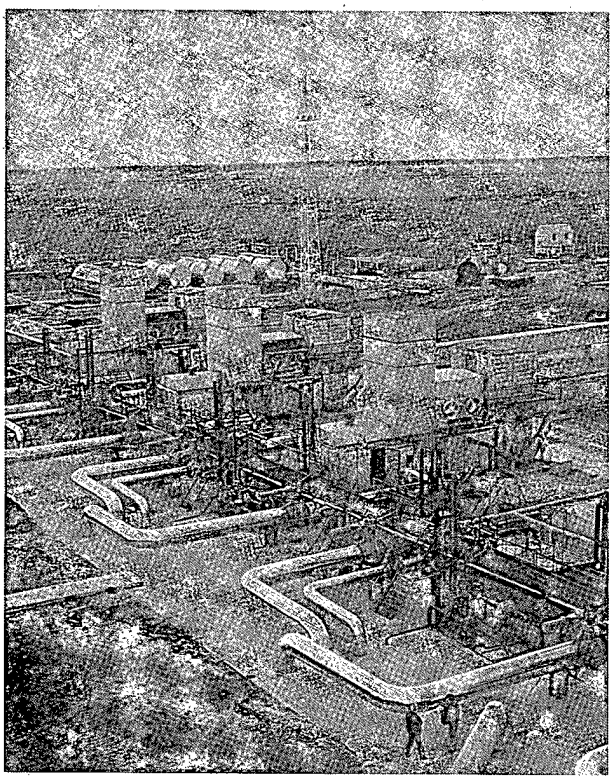

Figure 3. Compressor station equipped with Soviet aeroderivative gas turbines.

We believe that many of the problems associated with the USSR's current line of 16- and 25-MW gas pipeline turbines are the direct result of the crash effort to rapidly develop and serially produce these turbines. At the time of the US embargo, Moscow was motivated both by the practical need to increase the supply of domestically produced gas turbines and by an obsession with closing an exposed gap in Soviet technological prowess. To meet the ambitious production deadlines, Soviet designers and machine builders apparently cut corners. Designs were not adequately reviewed, and serial production was initiated before prototype testing was completed. working the bugs out of a prototype turbine is as much a trial-and-error procedure (requiring time and observation) as an engineering problem.

In addition to design flaws, some Soviet articles have highlighted poor production and assembly practices. One author noted that the low quality of some components was at times so obvious that the ministry simply appeared not to care about making improvements. The low quality of the turbines and the high incidence of failure is causing Moscow to spend large sums on repairs.[5]

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The reliability and performance of the GTN-16 and GTN-25 may now be so low that the Soviets may have to scrap their designs and develop a completely new turbine. An editor of the Soviet gas industry journal indicated that it would be "inexpedient" to attempt to improve the GTN-16 and GTN-25 turbines and that "decisive measures are needed to immediately begin development of a new generation of more reliable gas turbines for use in the 13th Five-Year Plan (1991-95)." This bleak assessment is in marked contrast to the glowing Soviet reviews shortly after the US embargo was imposed. For example, the GTN-25 was frequently compared to the best Western models and eventually received the "state seal of quality."

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The low reliability of Soviet 16- and 25-MW gas turbines may soon threaten the gas pipeline network's capacity to deliver adequate volumes of gas to consumers in the western regions of the USSR. One Soviet author noted that "a very tense situation is developing that could lead to difficulties in providing energy to the country." Although redundant capacity is available at each compressor station, the number of turbine failures is apparently so frequent that some stations cannot always keep the minimum number of units operational. Moreover, Soviet gas transport

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[5] Each repair on the GTN-25 reportedly costs about 350,000 rubles, and labor expenses for repairs are eight times greater than the norm established for repair and maintenance. Moreover, the transport associations are concerned that in the new system of self-financing they will not be able to write off expenses incurred in eliminating factory defects.

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officials are expecting more turbine failures, the complete shutdown of some stations, and a reduction in gas deliveries to the European region of the USSR.[6]

Outlook

Problems caused by the low reliability of the large numbers of 16- and 25-MW units currently in service, as well as those that will be installed by 1990, will continue to mount. As the share of these turbines increases, the overall reliability of the gas transport system will inevitably lessen. Moreover, the Soviet press has indicated that about 20 percent of the turbine capacity installed on the entire gas pipeline network will have outlived its service life by 1990 and will need to be replaced. Thus, gas transport system operators will be caught in a dilemma: new units off the assembly line will continue to be unreliable while the need to replace older capacity will be increasing. Despite Gorbachev's much trumpeted campaign to improve the quality of industrial production, the fruits of this effort have had little impact to date on the power machine building ministry's procedures for manufacturing gas pipeline turbines.

planned additions to the Soviet gas network indicate that by 1990 overall transport capacity will exceed projected average consumption and export levels by about 25 percent.[7] However, this excess capacity is not sufficient to meet peak winter demand in some regions because of inadequate gas storage capacity and a seasonal surge in demand that rises as much as 50 percent. The pipeline network transporting gas to the Baltic, Belorussian, and Leningrad regions (the Northern Lights system) apparently has been nearly fully utilized since 1985, limiting the system's flexibility to meet demand during peak periods. Thus, additional demands made by consumers in these regions during peak winter periods must be met by rerouting some domestic gas deliveries, rerouting export deliveries, and also by periodically curtailing flow to some areas. Because of the limited flexibility during peak periods, turbine failures forcing shutdowns of compressor stations on pipelines serving the Baltic, Belorussian, and Leningrad regions would result in additional curtailments in gas deliveries. 25X1

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the pipeline system transporting gas from West Siberia to the central and western regions of the USSR show that excess transport capacity—which is about 35 percent during periods of average demand—is cut in half during peak winter periods. During some winter months, excess capacity could fall to as little as 10 percent. Turbine failures would result in additional capacity erosion.[8] The margin between transport capacity and demand would become uncomfortably taut, and could lead to periodic reductions in gas deliveries to some areas in the central and western regions of the USSR. 25X1 25X1

If gas turbine failures threaten to curtail gas deliveries to the central and western regions, Moscow would almost certainly take immediate action to minimize any reduction in gas deliveries. Turbine repairs would be given priority treatment, and Moscow would use the pipeline system's flexibility to reroute gas to areas experiencing shortfalls. Nonetheless, because some of the system's flexibility already is used every winter to provide additional gas for the northern regions, there is less room to maneuver should problems occur on the main West Siberian pipeline corridor. In addition, large gas systems react very slowly to this type of rerouting operation, and two weeks may elapse before diverted gas reaches the intended area. 25X1 25X1 25X1 25X1

[6] The operation of the West Siberia–Western Europe gas export pipeline is unlikely to be threatened by the low reliability of Soviet turbines. Despite publicized claims that a large number of domestic turbines would be used on the gas export pipeline, Moscow essentially followed its original plans after delivery of the US Frame-5s was resumed. Imported gas turbines account for more than 80 percent of the power installed on the gas export pipeline.

[8] Engineering calculations show that the loss of just one station on a large-diameter pipeline operating at maximum throughput and pressure could result in a 15-percent drop in gas flow. 25X1

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Because natural gas will be the major source of growth in the USSR's energy supply in the next decade, Moscow can ill afford to have an unreliable gas pipeline network threaten to disrupt gas deliveries in the 1990s.[9] Many aspects of Moscow's Long-Term Energy Program are likely to fall short of expectations, increasing the pressure for expanded use of natural gas: progress in energy conservation is likely to be modest; prospects for stabilizing oil production are not good; coal production, instead of showing robust growth, is likely to limp forward; and growth of electricity production from nuclear power is likely to be slower than anticipated.

Implications

Regional disruptions in gas deliveries, if prolonged or exacerbated by increasingly frequent turbine breakdowns, could develop into a problem of national proportions. Disruptions in gas deliveries would at a minimum cause some consumers to switch to backup fuel oil supplies—if they were available. This would contribute to keeping oil consumption high and threaten to reduce the availability of oil for export. Because backup fuel oil supplies are also spread thin during peak-demand periods, gas disruptions could also lead to some regional reductions in electricity production and disruptions in industrial output. The USSR's electricity supply is already taut, and some key industries—such as steel and cement—are becoming increasingly dependent on natural gas. Moreover, Gorbachev's economic modernization program, which calls for both ambitious growth rates and a substantial replacement of capital stock, would be adversely affected by disruptions—even if temporary—in gas deliveries.

[9] Natural gas production is scheduled to grow from 727 billion m^3 in 1987 to roughly 1,100 billion m^3 in 1995.

Moscow has options available that would mitigate shortcomings in domestic 16- and 25-MW gas turbine performance and production. None, however, are likely to be palatable to the Soviets:

- The USSR could resume equipping compressor stations with a larger complement of smaller gas turbines, but this alternative would incur much higher capital and labor costs. Moreover, a large volume of construction material would have to be brought on site, and the time required for compressor station construction would be extended.

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- By installing more turbines at each compressor station, the USSR could increase the amount of redundant capacity. This would probably increase the overall reliability of the station, but it would also involve increased costs and probably constrain the production of turbines for other industries.

- The USSR could build more electric-drive compressor stations. The amount of electricity consumed by these units, however, is large. For example, 2,000 MW would be required to service a 4,000-km pipeline—an amount equal to the entire output of a large electric power plant—and would further strain already taut Soviet electricity supplies. Moreover, this option is not feasible in some areas—particularly east of the Urals—because pipeline corridors are not near power plants, line losses resulting from long-distance electricity transmission are substantial, and constructing transmission-line towers in permafrost regions is difficult.

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- Moscow could launch a major domestic effort to design, develop, test, and install new, more reliable turbines. Given the current state of Soviet manufacturing technology, however, such an effort would probably require several years to bear fruit. During this period, the gas transport system would remain

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vulnerable to breakdowns and consequent interruptions in gas deliveries. Moreover, despite requests from gas transport officials for a new generation of domestic turbines, we have seen no evidence that Moscow intends to launch a major new program for 16- and 25-MW turbines.

- The USSR could resume imports of Western gas turbines. Because of the hard times that have fallen on the world petroleum equipment industry, Western companies would welcome any opportunity to increase sales. Purchasing gas turbines from the West would require substantial outlays of hard currency or a runup in Soviet debt. About $1 billion would be required to equip just one of the six gas pipelines planned for construction during 1991-95 with Western turbines. Moreover, in light of their much publicized response to the 1981 embargo, this would be embarrassing to the Soviet leadership.

If gas turbine failures threaten to reduce oil available for export or to disrupt electricity generation and industrial production, we believe Moscow most likely would seek Western assistance. Given the current constraints on domestic investment and the relatively good credit position Moscow enjoys with Western bankers, importing turbines would be the least painful option, despite the embarrassment to the leadership.[11] It is also the quickest and most effective option for improving the reliability of the Soviet gas pipeline network. Such purchases would come mostly from Western Europe but some could come from the United States, especially if US turbine manufacturers pursued joint ventures with Moscow. The Soviets reportedly already have made inquiries to some Western firms about the availability of 10-, 16-, and 25-MW turbines. The US-USSR Joint Commercial Commission meeting scheduled next month could provide a forum for Moscow to pursue this issue with US businessmen.

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